Does Footprint Preparation Influence Tendon-to-Bone Healing After Rotator Cuff Repair in an Animal Model?

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Purpose: The aim of this study was to investigate the influence of footprint spongialization and radiofrequency ablation on rotator cuff repair outcomes compared with an untreated group in a rat model. **Methods:** We randomly assigned 189 Sprague-Dawley rats to either a spongialization, radiofrequency ablation, or untreated group. After separation of the supraspinatus tendon from the greater tubercle, the footprint was prepared by removing the cortical bone with a burr (spongialization), was prepared by ablating soft tissue with a radiofrequency ablation device, or was left unaltered (untreated). Biomechanical testing (after 7 weeks, n = 165) and histologic analysis after 1 and 7 weeks (n = 24) followed reinsertion. **Results:** The mean load to failure was 17.51 ± 4.46 N/mm^2 in the spongialization group, 15.56 ± 4.85 N/mm^2 in the radiofrequency ablation group, and 19.21 ± 5.19 N/mm^2 in the untreated group. A significant difference was found between the spongialization and radiofrequency ablation groups (P = .0409), as well as between the untreated and radiofrequency ablation groups (P = .0014). There was no significant difference between the spongialization and untreated groups (P = .2456). The mean area of fibrocartilage transition, characterized by the presence of type II collagen, was larger after 1 and 7 weeks in the spongialization group (0.57 ± 0.1 mm^2 and 0.58 ± 0.1 mm^2, respectively) and untreated group (0.51 ± 0.1 mm^2 and 0.51 ± 0.2 mm^2, respectively) than in the radiofrequency ablation group (0.11 ± 0.1 mm^2 and 0.4 ± 0.1 mm^2, respectively) with $P < .05$ and $P < .01$. **Conclusions:** The results of this study show that radiofrequency ablation of the footprint results in a poor biomechanical and histologic outcome in an animal model. No preparation of the footprint has the same effect as spongialization. **Clinical Relevance:** Different techniques of footprint preparation in rotator cuff repair may influence tendon-to-bone healing.

Open and, more recently, arthroscopic rotator cuff repair have shown good short-term results with respect to functional outcome and pain relief.[1,2] Nevertheless, many clinical studies report high instances of rotator cuff tears that do not heal very well after repair.[1,3-5] In most basic science studies, the main focus has been on improving repair techniques biomechanically, whereas recently, attention has shifted to biological aspects of tendon healing to improve tendon-to-bone healing.[6-8] Several authors have reported improved rotator cuff healing using biological augmentation with stem cells, growth factors, and platelet-rich plasma,[9-11] but current augmentation techniques have their limitations.[8] An important step in rotator cuff repair is the correct reduction of the tendon to the so-called footprint, the insertion area of the tendon onto the greater tuberosity. In the literature, no recommendations are available to the surgeon on how to prepare this area for optimal reinsertion of the avulsed tendon.[12-14] Clinically, radiofrequency devices are frequently used to prepare the footprint ablating soft tissue from the tendon insertion site, but their effect has never been studied. In addition, spongialization of the footprint with a burr before reinserting the tendon is also regularly performed. Since Randelli et al.[15] proved that growth factors are released after acromioplasty with partial spongialization of the acromion, we hypothesized that spongialization of the

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footprint may improve rotator cuff healing by the release of growth factors right underneath the reduced tendon. To our knowledge, there are only 2 studies focusing on a comparable hypothesis. Levy et al.[16] used cannulated humeral implants in rats to allow access of the bone marrow cells into the tendon insertion zone but did not find a significant influence after 4 and 8 weeks. In an earlier study, St. Pierre et al.[17] evaluated tendon healing to a cancellous trough in a goat model and also found no significant improvement after 6 and 12 weeks.

The aim of this study was to investigate the influence of footprint spongialization and radiofrequency ablation on rotator cuff repair outcomes compared with an untreated group in a rat model. Our hypothesis was that with spongialization of the footprint, functionally competent tendon-to-bone regeneration can be achieved that is superior to radiofrequency ablation.

Methods

Study Design and Experimental Groups

A rat model was used because of the similarities to the human anatomy and based on previous recommendations.[18,19] After approval was obtained from the Institutional Animal Care and Use Committee, 189 twelve-week-old Sprague-Dawley rats, with a mean weight of 250 g, were obtained (Charles River Laboratories, Sulzfeld, Germany). There was no difference in weight at the time of the operations among the groups. All animals were randomly assigned to either the spongialization, radiofrequency ablation, or untreated group. Furthermore, they were divided into a biomechanical arm and a histologic arm of testing, with 55 rats and 8 rats in each group, respectively. Biomechanical testing took place 7 weeks after surgery, whereas 4 animals from each subgroup were analyzed histologically after 1 week and 7 weeks. Figure 1 shows the classification of all groups and subgroups.

Surgical Technique

All rats were anesthetized with isoflurane followed by an intramuscular injection of 50-mg/kg ketamine and subcutaneous injection of enrofloxacin, 2.5 mg/kg of body weight, for antibiosis. During surgery, isoflurane and oxygen were administered by nose cone. All operations were performed under sterile conditions by a single surgeon (A.F.). The right shoulder region was shaved; the animals were put in the lateral position and kept warm with a heating pad. Only the right arm was operated on, allowing the rats to ambulate and feed. The skin incision was followed by a deltoid-splitting cut. To visualize the rotator cuff, the acromioclavicular joint was divided. The supraspinatus tendon was carefully identified and cut off at the insertion to the greater tuberosity. The tendon was dissected transverse; no dog-bone configuration was achieved. The footprint was prepared in 3 different ways, depending on the group assignment. In 1 group ($n = 63$) the cortical bone of the greater tuberosity was removed by a fine burr (Proxxon Micromot 50/EF; Proxxon, Föhren, Germany). In another group ($n = 63$) the soft tissue was completely ablated from the insertion area with the help of a bipolar radiofrequency ablation device (CoolCut 45 SJ; Arthrex, Munich, Germany). Finally, in the untreated group ($n = 63$), the tendon was reattached without any preparation of the footprint. Tendon repair was carried out with a single Mason-Allen stitch using a No. 5-0 double-armed Prolene suture (Ethicon, Somerville, NJ) through the supraspinatus tendon. On the greater tuberosity, 2 mm from the articular surface, two 0.5-mm tunnels were drilled. Both suture ends were passed through the tunnels and tied together on the humeral cortex, reconnecting the supraspinatus tendon and the differently prepared footprints. The deltoid split was closed with No. 3-0 Ethibond (Ethicon), and the skin was closed with No. 3-0 Vicryl subcutaneous suture (Ethicon).

For analgesia, the rats were subcutaneously given buprenorphine, 0.05 mg/kg of body weight, directly at 6 and 12 hours postoperatively. All animals were monitored according to the guidelines provided by the Institutional Animal Care and Use Committee for discomfort, distress, and pain.

Biomechanical Testing

The humerus, with its attached supraspinatus tendon and muscle, was carefully dissected from the scapula

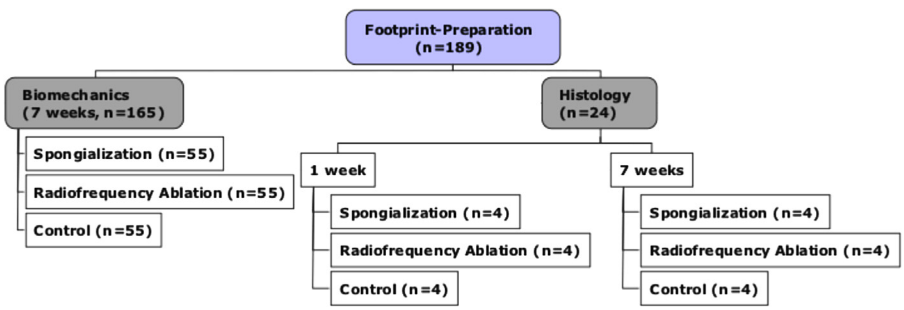

Fig 1. Study setup and number of animals in each group.